Australian Government
Department of Defence
Defence Science and
Technology Organisation

DSTO

A Review of US Army and Marine Command and Control Systems

Brendan J. Kirby and
Paul S. Gaertner

DSTO-TN-0596

Australian Government
Department of Defence
Defence Science and
Technology Organisation

A Review of US Army and Marine Command and Control Systems

Brendan J. Kirby and Paul S. Gaertner

Land Operations Division
Systems Sciences Laboratory

DSTO-TN-0596

ABSTRACT

The US Army Battle Command System (ABCS) is an integrated system of command and control software, computers, communications and networking devices. A summary of the ABCS is provided, giving an overview of how the Force XXI Battle Command Brigade and Below (FBCB2) system fits into the overarching scheme of providing battlefield awareness to the Army. FBCB2 aims to provide digital battle command and situational awareness to mounted and dismounted tactical combat, combat support, and combat service support commanders, leaders and soldiers. The US Marine's Integrated Marine Multi-Agent Command and Control System is also discussed in the light of the development of an Australian Battlefield Command Support System.

RELEASE LIMITATION

Approved for public release

Published by

DSTO Systems Sciences Laboratory
PO Box 1500
Edinburgh South Australia 5111 Australia

Telephone: (08) 8259 5555
Fax: (08) 8259 6567

AR 013-260

Submitted: June 2002
Published: November 2004

APPROVED FOR PUBLIC RELEASE

A Review of US Army and Marine Command and Control Systems

Executive Summary

The Australian Battlefield Command Support System (BCSS) is an evolutionary acquisition. Consequently, there is a requirement to gain an awareness of other developments in command support software and hardware that may feedback into improved operational capabilities and performance for the Australian system.

This review describes current developments in three systems:

1. The US Army Battle Command System: will be fielded to a vertically and horizontally integrated force that would allow warfighters to share a common battlefield view. This system facilitates interoperability with Joint level systems and a number of specialised systems all functioning in different areas, yet working together.

2. The US Force XXI Battle Command Brigade and Below: to provide on-the-move near-real-time battle command information and situation awareness. This system gives us the opportunity to see how a variety of platforms and HQ levels can be integrated into a cohesive network providing the communication of required information to all levels below Brigade. One powerful characteristic is its interoperability with all of the other systems that are being developed under the ABCS program.

3. The US Integrated Marine Multi-Agent Command and Control System: will be an adaptive command and control system using agent-based technology to tailor information processing and filtering for the user. This system will be able to assist with the development of the presentation of knowledge and understanding, rather than information and data as is currently the situation in the Australian systems. With assisted cognition and planning, this system could revolutionise our expectations of command support and situation awareness systems.

Authors

Brendan J. Kirby
Land Operations Division

Brendan graduated from Melbourne University with first class honours in 1983. He gained a PhD in applied nuclear techniques of analysis and mapped the first microscopic spatial distribution of copper in biological tissue (published in the Journ. of Inorganic Biochemistry). In 1989, as a Post Doctoral Fellow on physical aspects of Textile Processing with CSIRO, he derived a new theory of waste collection during worsted rectilinear combing (Journ. of the Textile Institute). This small team also set new world records for Comber speed over short intervals. In 1994, as a Research Fellow on x-ray physics at Monash University, he extended a parametrisation of the physics of the x-ray linear attenuation coefficient, thus obtaining absolute estimates of material parameters from monochromatic computed tomography for the first time without reference to a phantom calibration (Physics in Medicine and Biology). In 1998 Brendan joined LOD as a Research Scientist, working on applications to support Situation Awareness and Visualisation of the Battlespace. He has also worked on developing Enterprise Architectures, modelling in CORE the speed of command for different HQ configurations, taxonomies for the military complex adaptive system, and on various aspects and shortfalls of the NCW paradigm.

Paul S. Gaertner
Land Operations Division

Paul Gaertner completed his Ph.D. at the University of South Australia in Applied Mathematics in 1997. His Doctoral thesis was titled Optimisation of Integrated Models of the Enhanced Greenhouse Effect. In 1997-8 Dr Gaertner led the tactical command and control analysis as part of the Restructuring the Army project. In 1999 he was appointed a Senior Research Scientist and assigned to led DSTO input to the Army's Battlefield Command Support System project. In 2000 he undertook a defence science fellowship for 15-months to the RAND Arroyo Center in Santa Monica California, where he worked on issues relating to United States Army's Objective Force and Future Combat System. In 2002 he was promoted to a Principal Research Scientist and is currently Head Task Force Modernisation within Land Operations Division.

Contents

Glossary

A2C2	Army Airspace Command and Control
ABCS	Army Battle Command System
AFATDS	Advanced Field Artillery Tactical Data System
ASAS	All Source Analysis System
AMDPCS	Air and Missile Defence Planning and Control System
ATCCS	Army Tactical Command & Control System
AWE	Advanced Warfighting Experiment
BCSS	Battlefield Command Support System
BFA	Battlefield Functional Area
BPV	Battle Planning Visualisation
C2	Command and Control
C4I	Command, Control, Communications, Computing and Intelligence
C4ISR	Command, Control, Communications, Computing, Intelligence, Surveillance and Reconnaissance
CADRC	Collaborative Agent Design Research Centre
CCTT	Close Combat Tactical Trainer
CECOM	Communications & Electronics Command
COTS	Commercial off the Shelf
CSSCS	Combat Service Support Control System
DII	Defence Information Infrastructure
DTSS	Digital Topographical Support System
EPLRS	Enhanced Position Location Reporting System
EW	Electronic Warfare
FAADC2	Forward Area Air Defence Command and Control
FBCB2 – EBC	Force XXI Battle Command Brigade and Below – Embedded Battle Command
FDTE	Force Development Test and Experimentation
FT	Field Test
GCSS-A	Global Command and Control System – Army
GPS	Global Positioning System
IDA	Institute for Defence Analyses
IMETS	Integrated Meteorological System
IMMACCS	Integrated Marine Multi Agent Command & Control System
IOM	IMMACCS Object Model
IOTE	Initial Operational Test and Evaluation
IPB	Intelligent Preparation of the Battlefield
ISYSCON	Integrated SYStem CONtroller
IT&E	Integrated Test and Evaluation
IW	Information Warfare
JCDB	Joint Common Data Base
LUT	Limited User Trial
MAIS	Mobile Automated Instrumentation Suite
MCS	Manoeuvre Control System
MCTC – IS	Manoeuvre Combat Training Centre – Integration Systems
MCWL	Marine Corps Warfighting Laboratory
MILSATCOM	Military Satellite Communications
ModSAF	Modular Semi-Automated Forces
NCW	Network Centric Warfare
NIMA	National Imagery and Mapping Association (US)

NTDR	Near Term Digital Radio
OCL	Object Command Language
RCP	Relevant Common Picture
SA	Situation Awareness
SEP	System Evaluation Plan
SINGCARS	Single Channel Ground and Airborne Radio System
STORM	Simulation Testing Operations Rehearsal Model
TAIS	Tactical Airspace Integration System
TLCAC	Tactical Land C4I Assessment Capability
TRCS	Tactical Radio Communications Systems
USMC	United States Marine Corps
USMTF	United States Message Text Format
VMF	Variable Message Format
WIN	Warfighter Information Network

1. Introduction

Military commanders have always sought to know more about the environment of the Battlespace in which they have to interact, and to disseminate that information and knowledge down to subordinate commanders in the field. Conversely, subordinate commanders have often been frustrated by the lack of communication back to their commander from the battlefield. In today's context, the opportunity for information flow and knowledge transfer is much greater than in the past, and various systems are being developed in order to optimise the application of technology to meet these needs.

Command and control (C2) systems have advanced noticeably from the first systems developed that were primarily stand alone (stovepipe) workstations that did not share information between the various battlefield systems. Although some progress has been made to integrate cross-functional applications, emerging technology will facilitate more advances to make C2 systems more interoperable with legacy systems, various elements within a service, at the Joint level and also at the coalition level. These changes will include autonomous intelligent agents, integrated software modules, cross-service common applications, and the development of common displays and data models [1].

This document discusses the systems being developed for the US Army (focussing on the tactical level) and the US Marines Corps. The information on the Force XXI Battle command Brigade and Below system was obtained by Paul Gaertner on a visit to the US in 2000.

2. The Army Battle Command System

The Army Battle Command System (ABCS) is being developed by the US Army in order to achieve information superiority and optimum command and control for full spectrum dominance in the 21st century. ABCS systems form an integrated system of command and control software, computers, communications and networking devices, which can be used to lay the foundation for joint Network Centric Warfare (NCW). It is designed to provide commanders and their staff with accurate and timely information.

The operational concept of Joint Vision 2010 is a correlated, synchronised picture of the battle, enabling better, faster decision-making. This envisions the US Army XXI as a knowledge and capabilities based Army, capable of land force dominance across the spectrum of possible 21st century joint military operations [2].

The ABCS is the US Army's first step towards fulfilling the Joint Vision 2010. The goal of the ABCS is to achieve information superiority, and then dominant manoeuvre, precision engagement, full dimensional protection and focused logistics [3]. In order to achieve

information superiority, digitisation is essential; according to the US Army Modernisation Plan (1998): 'Digitisation is the application of information technologies to acquire, exchange, and employ timely information throughout the battlespace. It is a key element in support of the Army's concept for information dominance.'

3. Development of the ABCS

Communication and coordination needs are foremost for the army, especially when assets are widely distributed over a large area. The requirements for joint and combined operations are driving information systems towards a vertical and horizontal integrated system. NCW and Sensor to Shooter links are forged together by the information networks, to form a combined arms force, multiplying its ability to generate and communicate Situation Awareness (SA).

The ABCS was developed:

- To field a vertically and horizontally integrated force, that:
  1. Allows warfighters to share a common battlefield view;
  2. Enables leaders to:
     Reduce crew workload;
     Conduct automated Command and Control (C2) on the move, and
     Obtain automated targeting;
  3. Decreases decision-making time lines;
  4. Enables warfighters to operate inside the enemy's decision-making cycle.
- To enable warfighters to dominate the battlespace by synchronising combat operations, concentrating force effects, and preventing fratricide.

Battle command systems enable warfighters to operate more effectively by addressing conditions of uncertainty surrounding four areas:

1. Own location (where am I?),
2. Friendly locations,
3. Enemy locations,
4. What are the status, intent and activity of each friendly and enemy element?

By addressing these conditions of uncertainty, and accumulating information in these four areas, a battle command system can then consider these more detailed aspects of information handling:

- To report information in real time or near real time;
- To access information in a user-friendly format;
- To present information in a manageable format.

ABCS provides digital communications among strategic, operational and tactical headquarters, down to the soldier or weapon system level.

Three *battle command systems* interoperate within ABCS as follows:

1. ***Global Command and Control System-Army*** (GCCS-A) – the battle command system located at strategic and theatre levels. It interoperates with other theatre, joint and multinational C2 systems;
2. ***Army Tactical Command and Control System*** (ATCCS) – enhances battle command capabilities by synchronising the respective Battlefield Functional Area systems (BFA – these are similar to the Australian Army Battlefield Operating Systems);
3. ***Force XXI Battle Command Brigade and Below*** (FBCB2) – the battle command system that operates at brigade level down to the soldier or platform level.

Table 1: The Army Battle Command System key command and control systems

ABCS COMPONENT	SYSTEM	FUNCTION
AFATDS	Advanced Field Artillery Tactical Data System	Shows fire support range fans
ATCCS	Army Tactical Command and Control System	Synchronises respective battlefield functional area systems
FAADC2	Forward Area Air Defence Command and Control	Provides Air situation awareness for forward area commanders
CSSCS	Combat Service Support Control System	Shows logistics status
GCCS-A	Global Command and Control System, Army	Provides naval, marine and airforce situation awareness
FBCB2-EBC	Force XXI Battle Command Brigade and Below – Embedded Battle Command	Reports the location of friendly forces, up to the moment, near-real time, for all manoeuvre elements
IMETS	Integrated METeorological System	Adds weather data
TAIS	Tactical Airspace Integration System	Indicates safe air corridors
MCS	Manoeuvre Control System	Provide battlefield management
AMDPCS	Air and Missile Defence Planning and Control System	Delivers air defence coverage
DTSS	Digital Topographic Support System	Delivers terrain intelligence, visualisation and updated map backgrounds
ASAS	All-Source Analysis System	Indicates the position of enemy elements

Communication requirements for these battle command systems, and for the ABCS overall, is met by the Warfighter Information Network (WIN). Achieving information superiority via such a network is the foundation of ABCS.

The ABCS consists of the integration of the above battle command systems as well as a number of various command and control systems, as shown in Table 1.

3.1 ABCS Communications

The unified, synthesised Relevant Common Picture (RCP) relies heavily on the accuracy of its data. The data can only be as timely and beneficial as in proportion to the quality of the communication systems that link the soldiers in the field to each other and to their commander. The NCW paradigm is predicated upon robust, fault tolerant and automatic data communications.

At the tactical level, the warfighter's tactical internet consists of the Enhanced Position Location Reporting System (EPLRS), the Single Channel Ground and Airborne Radio System (SINCGARS), and the Near Term Digital Radio (NTDR). The secure communication systems, managed by the Integrated SYStem CONtroller (ISYSCON) ties the Army communications together[1].

The systems in Table 1 are all undergirded by the Joint Common Data Base (JCDB), with supporting communications, shown in Table 2.

Table 2: The Army Battle Command System supporting communications systems

COMMUNICATIONS	SYSTEM	FUNCTION
TRCS	Tactical Radio Communications Systems	Provides radio communication across the tactical environment
WIN – T	Warfighter's Information Network – Tactical	Ties the brigade to higher echelons
MILSATCOM	MILitary SATellite COMmunications	Provides satellite linkage back to higher HQ and information bases

The systems of the ABCS provide information relating to: terrain, weather, SA, manoeuvre control, air defence, artillery, intelligence and logistics (combat service support). Interoperability of ABCS at the joint and coalition level is supported by a common Defence Information Infrastructure (DII) and a RCP. Interoperability with legacy systems has also been achieved at the joint level and also to some extent with the systems of US allies.

[1] Appendix A indicates the ABCS component hardware, communications, message format, range of deployment, tactical information and intra-system message format.

3.2 Australia's Battlefield Command Support System

Concomitant with our knowledge of overseas developments in command support systems is the requirement to provide feedback and analysis of our own developments here in Australia. Australia's Battlefield Command Support System (BCSS), is a computer-based information system intended to provide command support functions to Army tactical commanders and their command teams. The system concept is to support both long range and near real-time tactical planning and decision-making both in barracks and in the field. The system is intended to operate in an environment characterised by geographical dispersion (a brigade can be spread across a 1000 km wide area in Northern Australia), insignificant or non-existent infrastructure, low bandwidth error-prone communications, highly mobile users and conflict. To provide flexibility and responsiveness to users' needs, the system architecture is based on utilising COTS technologies [18].

The key operational objective of BCSS is to improve combat capability through the application of information technology to the battlefield and to enhance decision–action cycles. This can be achieved by reducing the time taken from acquiring knowledge to making a decision; by improving the quality of decisions, and by providing high quality SA through the delivery and appropriate presentation of strategic, operational and tactical data and sensor information.

3.2.1 DSTO's Tactical Land C4I Assessment Capability

In order to provide an analysis environment for BCSS, DSTO is developing the Tactical Land C4I Assessment Capability (TLCAC) under the auspices of the Land Operations Division. TLCAC will provide an objective effectiveness measurement capability for various C2 systems. The initial coupling of the Janus brigade level wargame and BCSS Operations module has been completed, and this provides the modelling and simulation infrastructure for the TLCAC [19]. This provides an opportunity for greater versatility both in the range of systems investigated and in the maturity of the technologies involved. It is hoped that various US systems might be tested and analysed within this environment.

4. The US ABCS Program

The objective of the US ABCS is the integration of real-time situational information and sensor data into a force level database with simultaneous display and near real-time access as the commander and staff complete their common tactical picture at each echelon.

The components of the ABCS are the body of digital command, control, communication, computers and intelligence (C4I) systems that will automate the 'emerging digital force'. ABCS modifies the earlier mandate of the Manoeuvre Combat Training Centre Integration

Systems (MCTC-IS) to collect, record, analyse, and provide training feedback for digital force exercises. An interface is included to allow ABCS interaction with future MCTC simulations such as Warsim.

The components of the US Army digitisation program will now be discussed with emphasis on FBCB2, the last of the three core components of the ABCS.

4.1 Global Command and Control System – Army

The GCCS-A provides force tracking, host nation and civil affairs support, theatre air defence, targeting, psychological operations, command and control, logistics, medical and personnel status. GCCS-A is deployed from the theatre level (elements above Corps) to reach down to elements at the Corps level. GCCS-A is Army's link to the overall Global Command and Control System (GCCS) and to the Joint arena.

4.2 Army Tactical Command and Control Systems

The ATCCS provides the ABCS functionality from Corps down to Battalion level. It integrates and synchronises many of the battlefield functional area systems within ABCS.

Figure 1 illustrates some of the major components of the ABCS currently under development. Although these systems are individual software packages, they are all linked through the Joint Common Database. Some components of ATCCS are discussed below.

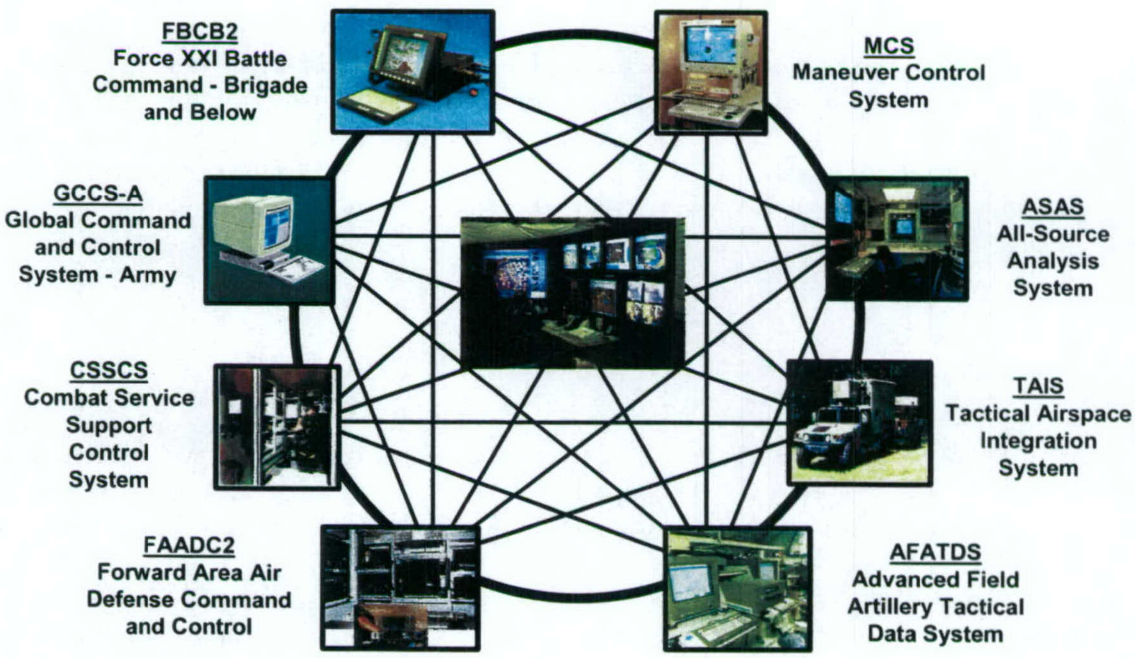


Figure 1: Some major components of the ABCS

4.2.1 Manoeuvre Control System

The Manoeuvre Control System (MCS) provides corps through battalion force level commanders and staff with the ability to collect, coordinate and act on near real-time battlefield information and to graphically visualise the battlefield.

The system integrates information horizontally and vertically to provide a common picture of friendly and enemy unit locations. Using MS-Word® and web browser templates, MCS technology provides the ability to develop and distribute battle plans and orders, and conduct multi-node collaborative planning sessions via 'show-me' whiteboards. MCS also provides active displays of the current status of personnel, equipment and supplies to support resource management staff decision-making.

MCS also provides the warfighter with a common tactical picture that encompasses a 'common look and feel' with other ABCS systems, high quality digital maps, drop and drag task reorganisation, OPORD generation, MS-Office® product automation, collaborative planning tools and role-based e-mail and messaging.

4.2.2 All Source Analysis System

The All Source Analysis System (ASAS) provides battle commanders with analysed intelligence and raw combat information. ASAS provides enemy SA fused from all sources (correlated and analysed intelligence), sensor feeds, reports, and combat information. ASAS also receives and displays imagery from national, theatre, and tactical sources and includes database and analysis tools that assist in collection, management and Intelligent Preparation of the Battlefield (IPB) functions. Essentially, ASAS maintains and displays timely detailed data on enemy units based on the latest combat information and intelligence.

ASAS also provides the warfighter with a common tactical picture with standard features, high quality digital maps, joint interoperability, a secret level red picture, and role-based (according to staff position and function) e-mail and messaging.

4.2.3 Advanced Field Artillery Tactical Data System

The Advanced Field Artillery Tactical Data System (AFATDS) provides command, control and communications for the US Army and Marine Corps cannon, rockets, missiles, mortars, close air support, and naval surface weapon systems. AFATDS capabilities include:

- Weapon-target pairing based on target type, commander's guidance, unit availability, weapon status, and ammunition availability;
- Digital SA from Army, Marine, and Air Force ground and air-based sensors, and other C4 systems;
- Automatic data distribution for timely coordination;

- Horizontal and vertical coordination through exchange of messages, maps and graphics overlays;
- Planning tools including fire support planning, route, and course of action analysis.

In addition, AFATDS will provide fire support coordination measures, weapon and counter battery radar range fans, and target data. Target data will include active, inactive, planned, on-call and suspect targets.

4.2.4 Combat Service Support Control System

The Combat Service Support Control System (CSSCS) provides battlefield decision-support and SA for planning and controlling the logistics support of combat operations. CSSCS provides material and personnel status of units and identifies logistical capability to resupply units for subsequent combat operations.

CSSCS capabilities include:
- Resource status summaries, display of current logistics information by class of supply, item, or unit, as colour coded charts or detailed reports;
- Course of action analysis, either as deliberate or quick analysis, using either current or planned task organisation based upon approved planning factors;
- A unit task organisation, which provides tracking of the task organisation down to company level with a structure for resource tracking;
- The commander's tracked items list (a subset of the baseline resource items list), which includes those command-interest and command-controlled items that are tracked by CSSCS.

Benefits to defence personnel include:
- A common tactical picture (similar to that for MCS) with standard display functionality and appearance;
- High quality digital maps;
- Potential for logistics redesign;
- CSS SA to combat commanders;
- Combat SA and C2 capability to CSS commanders;
- Support for warfighting C2 and the battle management process;
- Operational in real world and garrison situations;
- MS Office® product application;
- Role-based e-mail and messaging.

4.2.5 Integrated Meteorological System

The Integrated Meteorological System (IMETS) provides high-resolution current and forecast meteorological data and weather effects. IMETS capabilities include:
- An integrated weather-effects decision-aid-client to all BFAs for determining and displaying weather impacts on weapon systems;
- Weather overlays made available via maps and client overlays;

- Weather information made available via webpages;
- Severe weather warnings via US Message Text Format (USMTF) messages.

4.2.6 Digital Topographical Support System

The Digital Topographical Support System (DTSS) provides digital terrain analysis, terrain database(s), updated terrain products, and hard copy reproduction, in support of terrain visualisation, IPB and C2. DTSS capabilities include:
- Tactical decision aids (mobility analysis, intervisibility – or line of sight analysis – environment and climatology, terrain elevation, and special purpose products);
- Maps (from satellite imagery or a hard copy scan), or updates of digital topographic data where NIMA standard products do not exist or are outdated;
- A digital topographic data manager (which receives, manipulates, updates and distributes the NIMA digital terrain data) and a Global Positioning System (GPS) terrain data link.

4.2.7 Tactical Airspace Integration System

The Tactical Airspace Integration System (TAIS) provides Force XXI battle commanders with automated Army Airspace Command and Control (A2C2) planning, operations, and air traffic services. TAIS capabilities include:
- Automated A2C2 planning and deconfliction of messages;
- Automated A2C2 operations for monitoring real-time airspace situations, and deconflicting immediate requests;
- A modernised capability for improved provision of SA and communications.

4.2.8 The Battle Planning Visualisation System

The Battle Planning Visualisation (BPV) system provides animated course of action analysis, wargaming, planning, IPB and rehearsal tools. BPV capabilities include:
- Animation of planned or predicted unit movements;
- Two and three dimensional representation of terrain, friendly and enemy unit locations, and planned unit movement scenarios;
- Receipt of unit locations and tasking orders, and of enemy unit locations from ASAS.

4.3 Force XXI Battle Command Brigade and Below

The Force XXI Battle Command Brigade and Below (FBCB2) is one of the three battle command systems within the ABCS discussed above in section 2. FBCB2 is a digital, battle command information system that interfaces with the ATCCS located within the brigade and battalion, and is interoperable with Joint, Allied and Coalition forces [4]. This component is discussed in more detail in Section 5.

5. Force XXI Battle Command Brigade and Below

FBCB2 provides digital battle command and SA to mounted and dismounted tactical combat, combat support, and combat service support commanders, leaders and soldiers. This information is integrated, available on the move, in real-time or near-real time, and is accessible from brigade down to the soldier or platform level across all BFAs.

SA is a state of understanding that enables warfighters to observe, orient, decide and act, based on information supplied by a graphical battlefield RCP. Endsley summarises SA as 'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future' [6]. The SA capability provided by FBCB2 is paramount to warfighters, because warfighters that are aware of the battlespace can operate more effectively and achieve the basic tenets of SA, which are: initiative, agility, depth, synchronisation and versatility. One of the results of this awareness is that these warfighters will be less likely to fire upon friendly forces.

FBCB2 is currently located in the mounted and dismounted manoeuvre armour, reconnaissance, armoured cavalry, mechanised infantry, infantry and aviation units. These combined arms units report to the divisional headquarters or to the joint command authority and habitually have the CSS slice normally provided from the division. Figure 2 shows a terminal of FBCB2 illustrating its ruggedised case and push buttons on the case.

Figure 2: Force XXI Battle Command Brigade and Below system on a Ruggedised COTS Appliqué computer

Commanders and leaders rely upon the ABCS functional area systems GCCS-A, FBCB2, and the WIN to maintain a common tactical picture across all battlefield automated systems, while performing missions throughout the operational continuum. (ABCS combines mission applications with common applications and support software, DII Common Operating Environment products, protocols, and common hardware, in accordance with the Joint Technical Architecture.)

5.1 Capabilities

FBCB2 also integrates emerging and existing communication, weapon, and sensor systems to facilitate automated situation and combat awareness reporting. System capabilities are achieved through integration of all BFAs and ABCS capabilities.

Some of FBCB2 major capabilities include:

1. Visually display SA information;
2. Receive, develop and distribute a common battlefield picture;
3. Prepare and distribute orders and graphics;
4. Receive and input status information provided by weapons systems, sensors, and support platforms.

Existing logistics support organisations and the prescribed command maintenance will perform system support, sustainment and supply policies.

The system is designed to maintain a fully operational capability within the fielded standard Army maintenance system. Therefore facilitating relative ease of use by the operator to sustain functionality.

Other FBCB2 capabilities (perhaps not as significant as the above four major capabilities) include:

- Automatic exchange of digital information and status between ground forces and with air elements;
- Rapid acquisition, correlation and communication of target data to weapon platforms;
- On-board computer decision support aids;
- Remote operations and maintenance of ABCS database connectivity for commanders when away from their command posts;
- Tactical navigation aids;
- Creation, receipt, modification, filtering, prioritisation and storage of graphics and text files;
- Enhanced embedded training and help capabilities;
- Automated interfaces to training and simulation systems;
- Hands-free voice activation as a primary means for data entry and operation;
- Imagery and still frame video;
- Virus protection.

5.2 Implementation

Elements of FBCB2 include hardware, battle command software, Embedded Battle Command (EBC) software, and the tactical internet[2]. FBCB2 will be implemented in the following graded manner:

- FBCB2 hardware and battle command software as a stand-alone capability (minimal integration with platform);
- FBCB2 hardware and battle command software integrated with a platform (greater integration with other on-board systems);
- EBC software provided to platform project managers, who will integrate this software within their own embedded systems and who will retain ultimate control and responsibility for the integrity and performance of the platform;
- Battle command/EBC software integrated into ABCS workstations;
- FBCB2 co-hosted on another workstation.

FBCB2 will be interoperable with the current family of training and simulation systems (ie. the Close Combat Tactical Trainer) and with the WARSIM system. WARSIM will be capable of interoperating with FBCB2 in real-time. It also must maintain interoperability with FBCB2 during simulation restart, rollback, and similar changes in timing.

Coordination among the material, combat and training developers is essential to ensure interoperability between FBCB2 and the current and future family of simulations; which might be live, virtual, or constructive. This interoperability will allow commanders and staff access to synthetic, 'go to war' simulations systems. The interface will facilitate the upload and download of information from simulation databases to support terrain generation, scenario preparation (orders, force structure, status, positioning and weather), mission planning, mission rehearsal and after action reviews.

5.3 The FBCB2 mission

FBCB2 is the cornerstone of the information network, passing all its position location data through the tactical internet, allowing every manoeuvre element to know what their own position is, where other friendly elements are, and what the latest known locations of the enemy are. Data FBCB2 receives is obtained through the ASAS, via the ABCS Joint Common Data Base. Concomitantly, SA data can be transported through the Situation Awareness Data Link system, delivering supporting information to aircraft heads up displays.

FBCB2 consists of software for embedded air and ground platforms; hardware and software for non-embedded air and ground platforms; platform sensors and weapon systems interfaces; and supporting communications systems, to include interfaces to the WIN-T.

---

[2] Appendix B presents further information on FBCB2 Functionality, Display and Software Structure.

In addition to providing SA and a RCP, it is envisioned that FBCB2 meet role-based functionality, platform integration, communication and unit task organisation requirements as well.

ABCS is able to capture new capabilities as they come to fruition, and is inherently able to be redesigned and updated. For the upper tactical internet above FBCB2, the WIN-T has been created. The WIN-T is a secure communications and networking suite, which is designed to link Joint information from GCSS-A down to the tactical level. The need is for continuous communications in a non-contiguous battlespace.

ABCS in conjunction with the network, therefore, enables the ability to share SA and C2 information, with the goal of efficient use of resources within the enemy's decision cycle. This information flows from brigade to the soldier or platform level and across all BFAs.

5.4 FBCB2 Characteristics

FBCB2 has the following characteristics:

- Digital C2 System for the Army at brigade and below;
- Integrated, on-the-move, real-time or near-real-time battle command information via C2 messaging and SA;
- A sub-element and key component of the ABCS;
- Integrated into various weapons platforms;
- Several variants of FBCB2 exist:
  - Ruggedised COTS (Commercial Off The Shelf) Appliqué computer;
  - FBCB2 software on an Intel-based computer card integrated into weapons platforms – including Abrams M1A2 System Evaluation Plan (SEP) and Bradley M2A3 – known as Integrated Combat Command and Control;
  - EBC ported to a Linux operating system for all aviation platforms[3];
- FBCB2 systems linked via the tactical internet made up of EPLRS and SINCGARS radios.

5.5 Key Performance Parameters

FBCB2 has the following key performance parameters:

- Situation Awareness:
  Display own, friendly, enemy, and neutral elements and operational graphics;
- Interoperability:
  Seamlessly interoperate with Army, Joint and Allied/Coalition systems;
- Unit Task Reorganisation:
  Rapid re-establishment of digital communications in the event a task reorganisation is required;

[3] Refer to Appendix C for platform integration and test history; and a comparison of typical characteristics of analogue and digital command support systems.

- Information Exchange:
  Timely and reliable exchange of information;
- An increase in survivability, lethality and overall operational effectiveness.

5.6 US Army Test and Evaluation Command

The US Army Test and Evaluation Command has drafted the SEP for the FBCB2 system. The SEP defines measures to assess the operational effectiveness, suitability, and survivability of the FBCB2 system as a component of the ABCS. Essentially, the SEP provides a framework to assess the performance of the FBCB2 in a 'system-of-systems' environment, and describes an Integrated Test and Evaluation (IT&E) strategy to accomplish the system evaluation.

Lessons learned from the initial iterations of the SEP have provided invaluable information for the development and implementation of FBCB2 into the First Digitised Division. The FBCB2 IT&E strategy is based on a spiral (or evolutionary) development through continuous developmental and operational testing.

Developmental testing consists of:
- Contractor or government hardware qualification testing,
- System segment acceptance testings,
- Logistics demonstrations,
- Reliability demonstration testing,
- Central Technical Support Facility integration testing, and
- Three currently scheduled Field Tests (FT1, FT2 and FT3).

Operational testing will consist of
- Three Limited User Tests (LUT),
- A Force Development Test and Experimentation (FDTE), and
- An Initial Operational Test and Evaluation (IOTE).

5.7 The Relevant Common Picture

The RCP displayed by FBCB2 presents warfighters with an unprecedented way to visualise the battlefield. FBCB2 RCP elements include:
- The enemy situation (location, resources, status and possible actions);
- The friendly situation (location, resources, status, control measures and planned actions);
- Logistics (location and status).

The RCP provided to warfighters is automated to update itself when new status and location data are received. Additionally, redundant data is purged to present the information as one entity.

The foundation of the RCP is a digital map supported by a common database that provides topography derived from satellite and reconnaissance imagery. The RCP is scalable and tailorable, and is relevant to warfighters' respective interests and special needs, since it addresses their information requirements. Aspects of the RCP displayed and provided by FBCB2 are detailed below.

5.7.1 Role-Based Functionality

RCP development is accomplished via role-based functionality – providing information and system access privileges based on functionality requirements. Using role-based functionality, FBCB2 adjusts the digital information flow, thereby preventing information overload. Every time warfighters log in by duty position or role to FBCB2, they can only access the information relevant to that position or role. By providing warfighters this flexibility, they can readily assume a new position or role, or adapt to a different platform.

For example, if an armour company commander and his executive officer were disabled, the armour platoon leader could assume command by re-initialising the system, logging in and selecting functions performed by his commander. Security measures are installed to prevent unauthorised assumption of command.

5.7.2 Platform Integration

Due to the myriad of functions required of respective warfighters, it is imperative that the FBCB2 legacy and future platforms be integrated with automated systems to reduce interaction between the warfighter and the other automated systems on the host platform. For example, FBCB2 will be integrated with on-board weapon systems and sensor suites to optimise intelligence gathering and reporting, target identification and hand off, combat identification, SA and battlefield synchronisation. Likewise, computer modularity should accommodate multiple and removable displays on the host platform.

5.7.3 Communications

Currently, brigade and below warfighters typically pass verbal information over analogue radio nets structured in a hierarchical fashion. Consequently, warfighters usually pass information to the next higher or next lower echelon – very little information is passed horizontally. When an operation requires exchanging information horizontally, such as a passage of lines, a special radio net is established. Maps, overlays, operation plans and orders are transported by hand from one element to another.

Therefore, to obviate this dependence upon manual and limited radio communication, warfighters need a digital capability to exchange maps, overlays and operation plans and orders. FBCB2 will provide a mobile data communication network that supports digital information exchange, which will operate in various mission scenarios and over a wide range of terrain and environmental conditions. Warfighters need to make optimal decisions; consequently, the information must be timely, accurate and reliable. Therefore,

the message delivery rate is an important component of combat effectiveness, and must be above 90% in reliability (anything less than 90% reliability would severely decrease combat effectiveness).

5.7.4 Unit Task Organisation

Since various aspects of a task might change, such as the mission itself, enemy strength or location, the terrain, troop readiness, time available, or even a commander's unit composition; warfighters need a network capable of performing rapid unit task reorganisation. This may also require the re-establishing of digital communications. For example, the ability to task-reorganise aids the outgoing commander in planning, while permitting the incoming commander to track the new unit. It is to be expected that re-establishing digital communications in a dynamic environment without prior notice will occur even more frequently for modern warfighters.

6. IMMACCS

Military C2 requires information intensive activity in order to function. The information sources used are typically widely distributed, and decision-makers must understand and respond quickly under 'severe time constraints, incomplete information, and logistical limitations' [8]. During all phases, the situation continues to change, impacting both objectives and strategies for developing solutions. In order for decision-makers to understand and effectively respond to these changing circumstances, they require provision of 'alerts, inferences, and recommendations to identify critical aspects of the situation' [8].

The Integrated Marine Multi-Agent Command and Control System (IMMACCS) has a distributed and open architecture, and is an advanced C2 system providing tailored decision support [9]. This system is a first generation adaptive C2 system utilising expert-agent technology.

The primary purpose of IMMACCS is to assist its human users by collaborating with them, rather than automating the decision-making process. The emphasis is placed on providing the commander with tools to interact directly with the computer to solve problems. The human user and computer create a partnership that facilitates consensus decision-making, which results in a combination of the information processing power of a computer and the intuitive nature of the human mind [10].

IMMACCS achieves an adaptive capability through the use of agent based technology, and gives the operator a limited capability to tailor the information processing and filtering capabilities within the system [11].

The IMMACCS system provides an objectified picture of the battlespace to aid in exploiting opportunities and accelerating tempo. As a fire and manoeuvre system, IMMACCS disciplines the information environment and highlights factors affecting the commander's key concerns.

The principal components of IMMACCS (illustrated in Figure 3) include:

1. An internal IMMACCS Object Model (IOM)[4] where every entity in the battlespace (such as friendly and enemy assets, urban infrastructure elements, environmental phenomena, and operational events) is represented as an individual object with characteristics and relationships to other objects;
2. An Agent Engine which incorporates agents able to reason about characteristics and relationships of many real world entities and objects (such as mentor agents warning of enemy incursions across a geographic boundary). It provides a capability to reason about the current common view of the battlespace and several planning views;
3. A Shared Net communication system that provides subscription-based object-serving facilities (based on the CORBA architecture);
4. A graphical browser user-interface;
5. Translators for selected existing C2 software applications; and
6. Additional communication and visualisation facilities that provide a necessary level of redundancy in case of system failure.

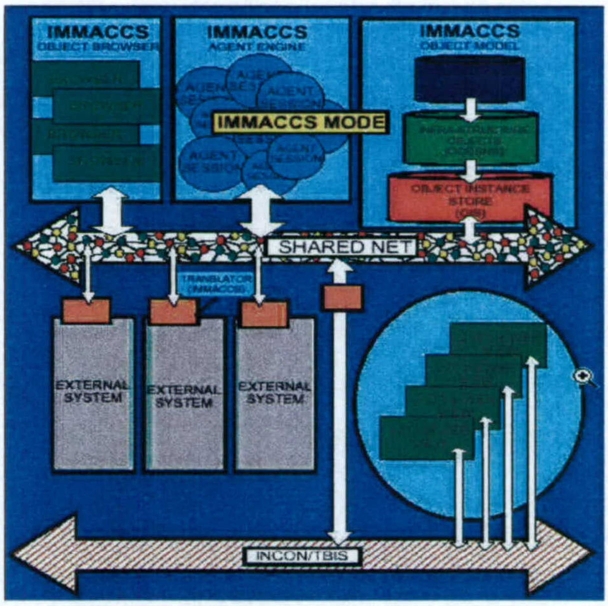


Figure 3: Illustrates each of the principal components of IMMACCS

[4] Refer to Appendix E for a description of the IMMACCS Object Model representation for Information and for Assets.

IMMACCS embodies four major design concepts as described below.

6.1 Object Representation

IMMACCS is an object based system that processes information – where information is data stored in such a representation that relationships between data are also stored. Therefore every entity in the battlespace is represented as an individual object with characteristics and relationships to other objects.

IMMACCS incorporates an object model that describes battlespace entities such as tanks, aircraft, supplies, bridges, buildings, roads, rivers, friendly and enemy units, and civilians in terms of behavioural characteristics and relationships to each other. For example, in legacy systems the interaction of the user with whatever is currently displayed on a computer screen is limited to a small number of predefined operations because the entire picture (or overlay) displayed on the screen, regardless of complexity, is presented to the user as a single object.

In IMMACCS every entity in the picture (including intangible entities such as weather, attack and defence) is represented as a real world object. Therefore, the user interacts with a computer display that consists of hundreds of real world entities (objects) that all have some 'understanding' of each other's nature, interests and objectives, and a high degree of understanding of their own behaviour and capabilities. Each of the IMMACCS components shares this IOM and therefore they can communicate with each other and the users in a common language.

Since IMMACCS has some understanding of the content of the data streams that flow through its components, it can incorporate agents with reasoning and other intelligent capabilities. Agents can perform various kinds of functions such as:

- Monitoring events that occur in the battlespace,
- Evaluating current conditions,
- Identifying conflicts,
- Proposing and evaluating alternative courses of action, and
- Pursuing the interests of specific entities, such as groups or individual persons or any other data objects included in the IOM.

6.2 User-Computer Collaboration

The primary purpose of IMMACCS is to assist its human users by collaborating with them, rather than by automating the decision-making process. The Agent Engine incorporates agents able to reason about characteristics and relationships of many real world entities. Operators interact with computer based agents. In this respect IMMACCS provides a partnership between complementary human and computer capabilities.

6.3 Problem solving tools rather than predetermined solutions

Naturally occurring problem situations cannot be predefined accurately especially those in the military environment. Therefore, predetermined solutions (in legacy computer systems) for particular problems seldom apply to real world situations. IMMACCS is a set of collaborative tools that can be applied dynamically both by users and the system itself to the current problem situation.

6.4 Integration of planning, execution and training capabilities

IMMACCS integrates planning, execution and training within one common C2 user environment. The collaborative tools that have been developed, are equally applicable to planning, execution and training scenarios, and can be applied in each of these areas. Therefore, users are able to continuously adapt to changing conditions in the battlespace by instituting dynamic re-planning and re-training operations [12].

6.5 IMMACCS Paradigm Shifts

6.5.1 Information Representation

Within IMMACCS, information is processed as knowledge in terms of real world objects with characteristics that describe their behaviour and capabilities, and associations that describe their relationships with each other [13]. In contrast with this, most currently existing software systems process data largely as text streams, numeric values, or text objects.

The IOM is comprehensive in content, containing

- Friendly and enemy assets (ie. weapons, supplies, equipment, munitions, personnel, organisations, etc.),
- The natural environment (atmospheric, climatic, astronomic, ocean, lakes, rivers),
- The artificial environment (mine-fields, buildings, utilities, transportation systems),
- Events, views, and other battlespace entities.

The IOM is compiled into a library that is used by each system component, and may be easily extended without compromising the integrity of individual system components. The existence of this common language allows computer-based agents to reason about real world events and present their suggestions utilising explanation facilities.

6.5.2 System Integration

IMMACCS is an integrated system of components with object-based knowledge-passing facilities, as shown in Figure 4 [14]. Each component shares a common language represented by the IOM library and utilises the subscription services that the Shared Net object-serving communication system makes available to its clients.

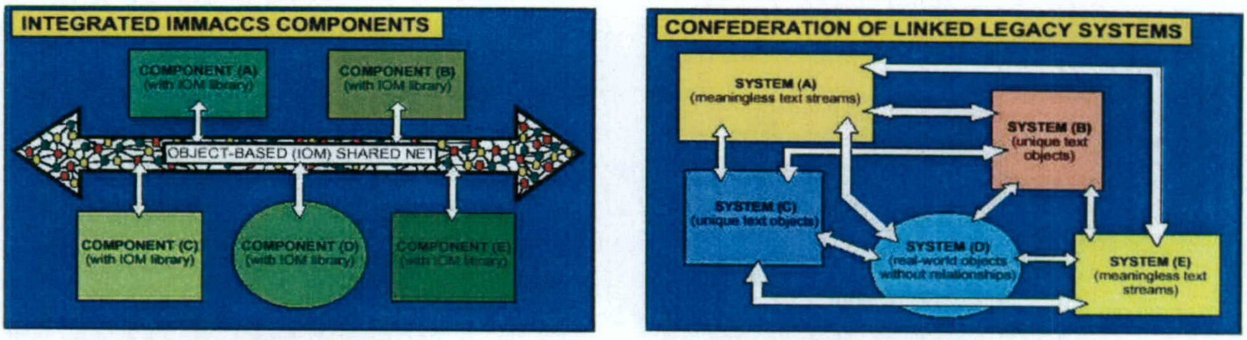


Figure 4: Illustrates the integration of IMMACCS components and the disparate nature of legacy systems

This is quite different to past confederations of linked legacy systems with predefined data flow paths.

6.5.3 Inter-System Communication

IMMACCS utilises Internet-based communication among its system components through subscription and query services. As information that is of interest to a particular Shared Net client becomes available, the client is notified and can then retrieve the information from the Shared Net (refer to Figure 5). To optimise performance a caching mechanism is employed. In addition to these automatic information updates, clients may seek other specific information by sending queries to the Shared Net. Again, this is in contrast with existing legacy system communication techniques with limited data flow and translation from other systems.

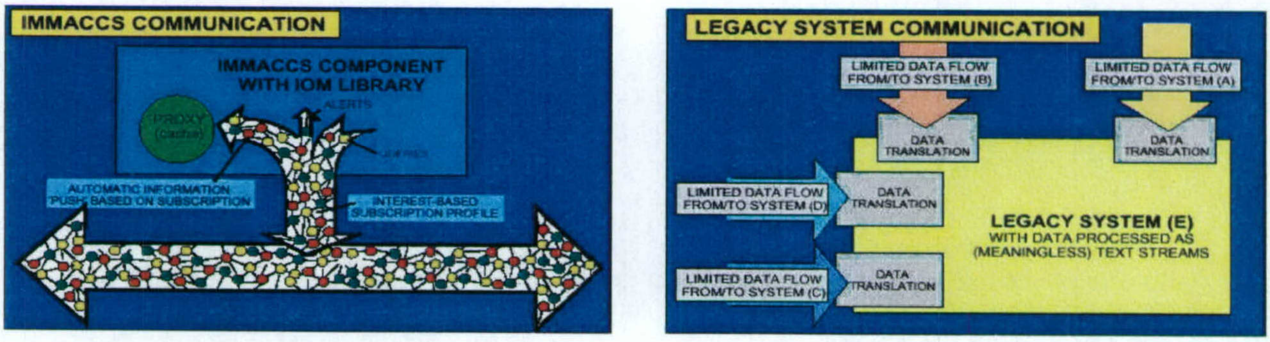


Figure 5: Illustrates the communication of IMMACCS components across the Shared Net middleware; as opposed to limited data flow and restricted translation from other systems

6.5.4 System Architecture

IMMACCS employs an open architecture, and thereby overcomes the inflexibility and fragility of stove-piped legacy systems that rely on hard-wired and predefined data channels (refer to Figure 6). In this open architecture, object-based application,

components may be freely added or deleted without jeopardising the integrity of the entire system [14].

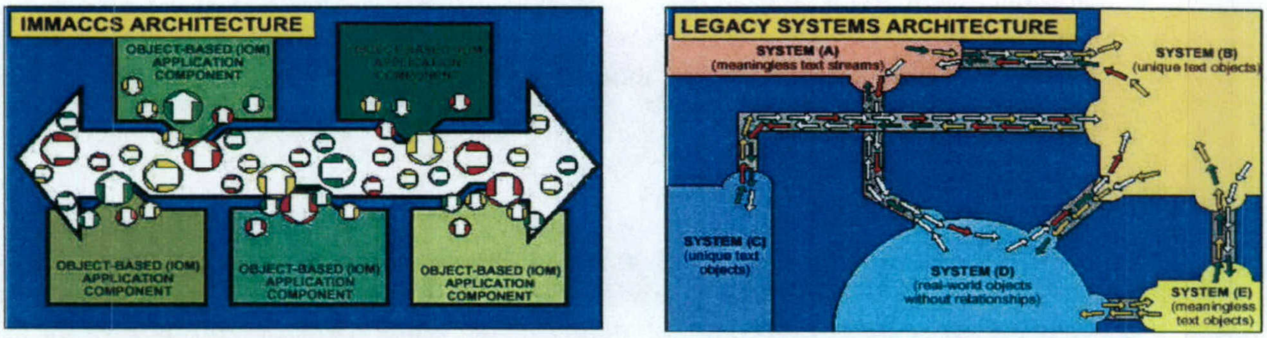


Figure 6: Illustrates the integration of IMMACCS objects and its architecture; in contrast with the stove-piped structure of legacy systems

6.5.5 Information Integration

In IMMACCS, the fragmented views of the battlespace that have in the past been spread over several legacy application systems are combined into 'one common view of the battlespace' that may be viewed by an authorised user on one computer screen at any access point.

6.5.6 Information Understanding

Within IMMACCS all views are represented as interactive real world objects with internal meaning to the system. The Collaborative Agent Design Research Centre (CADRC) emphasises that 'the IMMACCS environment can support computer-based agents capable of reasoning about events in the battlespace and providing analysis and interpretation assistance to the human decision-makers' [14]. This is unlike existing legacy systems where views of the battlespace are represented as bitmaps that must be filtered and interpreted by the user.

6.5.7 Real World Responsiveness

Within the IMMACCS decision-making environment, users and expert agents collaborate with computer-based decision-support tools to address unconstrained, naturally occurring, real world problem situations [14, 15]. Hence, the emphasis is placed on providing the user with tools to interact directly with the computer to solve problems.

6.6 IMMACCS Agents

The IMMACCS Agent Engine automatically initiates an 'Agent Session' whenever any user creates a new 'view' [14]. These agent sessions execute in parallel and may comprise any combination of the following kinds of agents:

1. Monitor Agents – monitor events in the battlespace;
2. Service Agents – have deep knowledge in narrow domains and provide expert services to other agents and users;
3. Planning Agents – specialise in planning tasks;
4. Mentor Agents – represent the interests of particular objects in the battlespace,
5. Coordination Agents – identify collaborative conflicts.

6.7 Object Command Language

IMMACCS incorporates an Object Command Language (OCL) that allows users to store Operation Plan and Operation Order information. This information serves as a context for agent sessions for analysis, planning, servicing and coordination tasks, within the user's view. During mission analysis and planning stages, the OCL provides search and reporting capabilities in support of the IPB process [14].

6.8 Application

IMMACCS was field-tested during the urban warrior Advanced Warfighting Experiment (AWE) conducted by the Marine Corps Warfighting Laboratory (MCWL) on the California Central Coast in March, 1999. It proved to be a functional success, and the concept of providing effective and adaptive decision-support through the use of collaborative expert agents was essentially validated [16]. Although basic functionality was demonstrated, improvements are required in various areas. IMMACCS was in full scale Version 2.0 development in preparation for Capable Warrior, which occurred June 25-29, 1999 at Camp Pendleton in San Diego [17].

7. Discussion

As discussed in section 3, DSTO's TLCAC might be employed to investigate various C2 and command support systems. It would also be advantageous to experiment with FBCB2, to look at different aspects of its application during the recent Limited User Trial II, and to investigate the possible formation of links to BCSS. It would also be of benefit to study issues relating to the experimental methodology, analysis and integration of digital systems supporting Force XXI. Ideally, this would also include a study of the IMMACCS system.

7.1 Interoperability of ABCS and BCSS

Close observation and understanding of current advances in ABCS and its associated tools and systems is essential in order to provide feedback and direction in the development of BCSS. BCSS is an evolutionary acquisition, and therefore there is an obligation to maintain an awareness of developments in both C2 software and hardware around the world, and

of implementations that may result in upgraded operational capabilities and performance. Consequently, there is value to be gained in learning from the experiences of other countries. New applications continually need to be sought out and assessed. Another immediate benefit to Australia is that the greater knowledge of other command support systems will lead to more insight into issues of interoperability [20]. This could then lead to the possibility of achieving interoperability with FBCB2, or even linking BCSS and FBCB2 for direct communication. This would make progress towards interoperability between the US ABCS and the Australian BCSS.

7.2 Support for the Urban Warrior for MOUT

In general, an impression could be obtained that command support systems or decision support tools are designed primarily for the rural terrain. These tools will need to be adaptable so as to support operations in urban terrain, as this is a highly likely location for future conflict (by 2020 more than 70% of the world's population will live in cities near coastal areas [17]).

Operations in Urban Terrain are an area where the development of decision support tools and command support systems should keep up to date. Rural terrain is far different to urban terrain, and systems will need to be able to cope with operations in both environments. For operations where a variety of contingencies are probable, an open system with adaptive C2 such as IMMACCS portends to provide strong support when confronted with unanticipated circumstances. A team in the US used IMMACCS to support its Exercise Urban Warrior (June 2001) and tested its ability to provide adaptive C2 to the user[5].

7.3 Impact on Mission Orders

An important, and currently an avidly debated, question is the impact that improved C2 will have on manoeuvre warfare doctrine and especially the concept of mission orders. Mission orders initially emerged to overcome the commander's information deficit during operations, and thereby to provide the subordinate commander with the opportunity to utilise his discretion and initiative. Today, with the rapid development of information technology and information processing, a more vertical, centralised battle command could result. The question, 'Will information superiority eliminate the fog of war and negate the relevance or necessity of mission orders in the Army After Next?' becomes central to the Army's evolving doctrine [7]. One resulting proposal is to integrate information superiority with the current doctrine (which includes mission orders) in a balanced manner in order to provide appropriate battle command for 21st century dominant manoeuvre.

[5] Refer to Appendix D for more detail on the planned application of IMMACCS to Exercise Urban Warrior.

Under the direction of the Army Digitisation Office, information superiority allows senior commanders to consolidate decision-making. Systems such as the FBCB2 – EBC and the MCS (with GPS), enable senior commanders to reach down several levels for near real-time understanding of the battlespace.

Various doctrinal authors have anticipated the potential disproportionate influence and impact of technology on battle command. Different departments have emphasised that battle command and battlespace visualisation should remain human endeavours that IT systems cannot fully supplant. Neither large nor small unit commanders are able to visualise the battlefield and direct or synchronise the efforts of their units from a computer screen at the command post. Commanders will most likely continue to be required to visit subordinate commanders and soldiers to assess the battle first-hand, and to perceive the abiding level of morale [7].

8. Conclusion

This report has provided an overview of the overarching US system ABCS, and a detailed look at the brigade and below battle command system in support of Force XXI, the FBCB2 C2 system. FBCB2 is the principal digital C2 system for the US army at brigade and below.

An introduction to the IMMACCS development was provided. IMMACCS is a distributed, open architecture, advanced C2 system providing tailored decision support. It is a first-generation adaptive C2 system utilising expert-agent technology, and may well change current thinking about C2 systems.

A brief overview of the Australian battlefield command support system, BCSS, was provided in the context of relating it to the US systems to enable further testing and evaluation of both current concepts and the direction of the evolving development. The important lesson for the Australian Army is to maintain a constant awareness of the developments that Australia's major allies are undertaking in providing digital support for their military forces. With this awareness, programs and ideas can be adapted so that the evolution of BCSS and other systems are kept in touch with the latest software, middleware, connection technologies and architectural structures. Only then can the command systems that the Australian military employ be optimised.

Currently, neither the Australian Army nor DSTO have devised a clear evaluation plan for the BCSS. In the US, lessons learned from the initial iterations of the FBCB2 SEP have provided invaluable information for the development of FBCB2, and its implementation into the First Digitised Division [5]. It is hoped that a system evaluation plan could also be implemented to monitor, direct and evaluate the development of Australia's command support system.

9. References

[1] D. Sauter, M. Torres, S. McGee and R. Okrasinski, Leveraging Command and Control Technology to Provide Advanced Environmental Effects Decision Aids On The Battlefield, Proc. 5th ICCRTS 2000.

[2] Land Warfare Studies Centre Working Paper No. 104, *The Implications of the United States Army's Army-After-Next Concepts for the Australian Army,* Lieutenant Colonel G. de Somer, June 1999.

[3] Joint Visitor Bureau, Daily Briefing 07 – 10 April 2000 rev.2, produced for PEOC3S by TRW.

[4] *Battle Command Systems: The Force XXI Warfighter's Advantage* by Major Mark C. Malham, US Army, and Debora Gabbard *Military Review*, 33 Mar/April 1998.

[5] P. Gaertner, Visit to the United States in April-May 2000 (personal communication)

[6] *Situation Awareness Analysis and Measurement* Ed. by M. Endsley and D. J. Garland, SA Technologies, Inc. (2000).

[7] US Army Field Manual 100-6: Information Operations, Washington, DC: Government Printing Office, August 1996.

[8] *http://www.cadrc.calpoly.edu/Projects/immaccs.html* (as at 13/6/01).

[9] Collaborative Agent Design Research Centre, California Polytechnic State University, San Luis Obispo, CA 93407; *http://www.cadrc.calpoly.edu/Projects/immaccs.html (June 2001).*

[10] *IMMACCS: A Military Decision-Support System*, J. Pohl, A. Wood, K. Pohl and A. Chapman, Proceedings of DARPA-JFACC Symposium on Advances in Enterprise Control, San Diego, CA; Nov 15-16 (1999). *http://www.darpa.mil/iso/jfacc/aec-symp.htm*

[11] The IMMACCS project is sponsored by the Marine Corps Warfighting Laboratory, Quantico (VA) June, 2001.

[12] *IMMACCS: An Experimental Multi-Agent C2 System*, J. Pohl, A. Wood and K. Pohl; Proc. of 5th ICCRTS, War Memorial, Canberra, October 2000.

[13] *IMMACCS After Action Report* (April 99), Leighton *et al*, Collaborative Agent Design Research Center.

[14] *IMMACCS Common View of the Battlespace at any access node*, by Collaborative Agent Design Research Centre (CADRC) *http:www.cadrc.calypoly.edu/projects/immaccs.html*

[15] *Transition from Data to Information*, J. Pohl, CADRC Technical Paper, Nov. 27, 2000, Cal Poly San Luis Obispo, CA, USA.

[16] *IMMACCS A Multi-Agent Decision Support System*, J. Pohl et al (CADRC) and T. McVittie (JPL) August 1999 Design Institute Report: CADRU-12-99.

[17] *CADRC Currents* April 2001 *http://www.cadrc.calpoly.edu/*

[18] Gaertner P., Slade M., Bowden F., Stagg B. and Huf. S., *Battlespace awareness and the Australian Army battlefield command support system*, Proceedings SPIE AeroSense 2000: Digitisation of the Battlespace V Conference, April 24-28, 2000.

[19] Bowden F. and Williams P., *Tactical Land C4I Assessment Capability Phase One Completion Report*, DSTO-TN-0258 April 2000.

[20] Nutwell, R. M. and Price, D. *A Common Footing, a prescription for improving information interoperability in multinational operations*, Armed Forces Journal Int. Nov. 2000 p. 32.

Appendix A: ABCS parameter values

This Appendix lists ABCS component hardware, communications, message format, range of deployment, tactical information and intra-system message format.

SYSTEM ACRO-NYM	SYSTEM NOMEN-CLATURE	HARD-WARE	COMMS	MESSAGE FORMAT	DEPLOYED	TACTICAL INFOR-MATION	INTRA-SYSTEM MESSAGE FORMAT
MCS	MANOEUVRE CONTROL SYSTEM	CHS II (SUN) SOLARIS	MPN	USMTF	CORPS (down to) BATTALION	C2 OVERLAYS SITUATION AWARENESS	USMTF
AMDWS	AIR & MISSILE DEFENSE WORK STATION	CHS II (SUN) SOLARIS	EPLRS BN (down to) SINCGARS BN (down to) MPN (up)	FDL FAAD DATA UNK	AD BN (down to) DW AMG CO	C2 SITUATION AWARENESS AIR PICTURE EARLY WARNING	USMTF
CSSCS	COMBAT SERVICE SUPPORT COMPUTER SYSTEM	CHS II (SUN)	MPN	USMTF	DIV (down to) BATTALION	LOGISTICS AWARENESS PREPLANNING REAL TIME ANALYSIS	USMTF
ASAS CSTAR Imple-mentation	ALL SOURCE ANALYSIS SYSTEM		CHS II (SUN) (down)	UNIQUE	DIV (down to) BRIGADE	INTELLIGENCE TARGET DEVELOPMENT TARGET IDENT-IFICATION	USMTF AFATDS
AFATDS FSATS Imple-mentation	ADVANCED FIELD ARTILLERY TACTICAL DATA SYSTEM	CH I HP735	MPN BN (down to) SINCGARS BN (down to) EPLRS	TACFIRE V10 AFATDS	CORPS (down to) PLATOON SECTION TM	ARTILLERY C2 FIRE SUPPORT	USMTF
FBCB2 APPLIQUE	FORCE XXI BATTLE COMMAND BRIGADE & BELOW	CHS II (OTHERS) INTEL	TACTICAL INTERNET	APPLIQUE (UKN)	BATTALION (down)	SITUATION AWARENESS	USMTF

Appendix B: FBCB2 functionality

FBCB2 will interface with other ABCS systems at brigade and battalion Tactical Operating Centres (TOC). It is hoped to achieve order of magnitude increases in survivability, lethality, and overall operational effectiveness and tempo.

Knowledge of blue and red platform positions increases survivability, lethality and operation tempo. Anything that has a geographic reference can be displayed as SA – blue, red or neutral. Geographic background can be: map, semi digital map, full digital map, still imagery, or live imagery.

FBCB2 DISPLAY PANEL

SA – where am I, where are my buddies, and where is the enemy? Geo-reference data including bridges, minefields and hazard areas etc. Pan box (or battlefield context display) shows platforms outside map area, displays enemy and friendly platforms, put your finger on the rectangle and slide to move to an adjacent area. Blue SA is hands free. Devotes most of the screen area to the map.

C2 Messages – Warnings and alerts displayed in a scrolling marquee and alarm, create long form and combat messages, JVMF messages only, address to person, group or everyone, FIPR precedence, machine acknowledgment, operator acknowledgment, operator response, C2 messages auto-generate geo-reference SA.

Other characteristics

- Zulu Date Time Group (DTG);
- Status 'gumballs' GPS, Comms;
- Displays FIPR (Flash/Immediate/Priority/Routine) message queue counters;
- Cautions, warnings, alerts scroll and provide audible alarm;
- **MAP BACKGROUND CAN BE EITHER CADRG, DTED, IMAGERY OR OTHER STANDARD NIMA PRODUCTS, OR COMBINATIONS THEREOF;**
- Most of the screen is used by the FBCB2 map;
- Map contrast and brightness controllable separate from icons and overlays;
- A short form message window, which minimises user input for fast operation with one button to send with predefined addresses (i.e. user-definable single-keystroke message send);
- User-adjustable single keystroke message send buttons;
- Auto-centre mode (user settable) toggle button to keep the map centred on own position;
- View top priority messages,
- Displays your own role label and own location;
- Cursor location – with display options for MGRS, Lat/long and UTM;
- Main menu buttons located to minimise hand-eye movement, better operate-on-the-move support, Rest your hand on the edge of the display and touch the buttons with your thumb or fingers;

Map zoom control,
Local time.

Commander's Decision Aids
Graphical Commander's Intent, Route planning and movement analysis, Course of Action Analysis, Imagery, Targetting.

B.1. Current and Future FBCB2 Testing

Tests to date have included FT1 and LUT1. The Government portion of FT1 employed 61 FBCB2 terminals and associated communications systems to examine the readiness of version 2.1 software to enter LUT1. Electronic Warfare (EW) and Information Warfare (IW) attacks were also conducted during FT1.

Future testing has been planned to include: FT2, FDTE/LUT2, FT3, LUT3 and IOTE. If the IOTE is successful, FBCB2 will be deployed to units for operational use. Prior to each field test there will be a series of developmental test events that include testing on software, hardware qualification testing, integration testing, safety testing and various survivability tests. In-plant testing and contractor testing will be used to test software versions in a test-fix-test mode to ensure readiness for Government testing. Field Tests 2 and 3 will use sufficient FBCB2 terminals and associated communications systems to assist the readiness of systems intended to participate in the operational tests.

The final IOTE will use two battalion task forces, each belonging to different exercise brigade headquarters, a division tactical command post, and additional manoeuvre forces simulated by the Simulation Testing Operations Rehearsal Model (STORM). The purpose of the IOTE and prior events is to determine the operational effectiveness, suitability, and survivability of the FBCB2 system in support of operational objectives.

The aim of the FBCB2 FDTE LUT2 is to evaluate the operational effectiveness of the system across and within echelons, validate the tactical operations centre; investigate electronic and information warfare; and evaluate the STORM model. The general approach is to perform active continuous evaluations through participation in key program events, as well as documentation reviews (to include results of studies, analyses, and modelling).

FBCB2 Software Structure

Back End Processes: EBC provides core functionality, abstracted such that the platform need not be concerned with the actual implementation of:
Communications interface, JVMF messaging, C2 Message handling, SA Message handling, System database, EBC API's, Platform interfaces, UTO Processing;
these are the minimum components required to be interoperable on the battlefield.

Front End Processes
SMI, Map display server, Symbology, Logistics processing, Commander's decision aids, Course of action analysis, Commander's Graphical intent, Route planning, Mission data load utility.

EBC insulates the platform from: the rapidly evolving Tactical Internet, the JVMF message set and the SA concept; and results in significant cost and risk reduction for the Army in development, integration testing, fielding, training and maintenance.

Hardware

Touch-screen: with 800 x 600 resolution, sunlight readable, wide viewing angle, 10 and 12 inch, 8 hard buttons for Bradley / Abrams.
Keyboard: Environmentally sealed, built in cursor control, back lit for night ops,
Production processor: solaris X86 OS, Pentium Mobile module 300 Mhz, 64 Mb RAM expandable to 256 Mb, 4.0 Gb hard drive, universal serial bus which supports out of the box peripherals, sensors and load devices, Universal shock mounted install plate and Mil spec connectors.
Production and fielding plan: US Army acquisition objective is over 59,000 by 2013.

Appendix C: Comparison of characteristics

A comparison of typical characteristics of analogue and digital command support systems carried out by the developers of FBCB2:

C.1. Analogue

Limited Battlespace Awareness; Limited Information; Limited Info Sharing; Labour Intensive Communications; Delays in Information; Limited Battlespace; Long Decision Cycles; Labour Intensive Information Processing Robs Time from Information Analysis; Mandatory Relay of Fire Requests; Movement to Contact Missions;

C.2. Digital

Expanded Battlespace Awareness; *Accurate Information;* Automation; Information Shared Throughout the Force; Timely Information; Expanded Battlespace; Decreased Fratricide; Shorter Decision Cycles – Maintain the Initiative; Automatic and Hands Free Info Processing Frees Time for Info Analysis and Other Tasks; Sensor to Shooter Possibilities; Movement to Engagement.

LRIP Computers (Appliqué+ V4)
Provided By Litton Data Systems and PARAVANT Inc.
TRW Competition: Several months of environmental stress testing with emphasis on disk drive, power supply, and temperature extremes
- Universal Serial Bus (USB) for sensor, loader, plug and play
- Increased processor speed and disk capacity
- Lower power chips
- LRU interchangeability = Processors, displays, and keyboards
- Identical form factor to protect IK investments

Both hardware & contract designed to facilitate technology insertion
Sunlight readable display Wide viewing angle; Touch screen; Pentium processor; Commercial hard disk drive in removable package; Meets environmental conditions for combat platforms (ruggedised, not 'militarised'); Standard interfaces

C.3. Platform Integration Method

Installation is either complete or in progress for the platforms listed below:
Appliqué; M109 Van; M2A2 ODS; M1064AX Mortar; M981AX FIST-V; M9 ACE; M548A3 Volcano; M577 Medical; M577 Mortar; M113 A2, A3; M88A2; M1059 Smoke; M58 A1 Smoke; M977 HMMWV ; AMB; M988/M1026; M93A1 Fox; M1031 CUCV; M1075 PLS; M939 Series 5-Ton; M982A2 FAASV; M1097 RWS; M1068 SICPS; M934 Expando; M35 2-1/2 Ton; HCMT; SICPS Tent; Grizzley; HEMTT; M966 TOW; ASV; M1114 HMMWV; Wolverine; BFIST/STRIKER; FMTV; M1070 HET;

C.4. FBCB2 Test History

PURPOSE: Provide an overview of the FBCB2 FDTE/CT. Beginning with TFXXI, the progression in time is downwards:
Task Force XXI

Version 1.x

Technical Problems; Static Addressing; Jury-rigged ATCCS Interface; FT1; New Arch; New HW;

Version 2.x

LUT; Interim C2 fixes; Limited ATCCS Interface; FT2; Blue SA; Risk Mitigation; Fightability; UTO; FOTE CT;

Version 3.x

LUT3; IOTE; Dynamic Addressing; Obj Arch Obj ATCCS Int Obj HW;

Appendix D: Application of IMMACCS to Exercise Urban Warrior

The military exercise, Urban Warrior, will experiment with a C2 system specifically designed to maximise the capabilities of the data environment. IMMACCS will be the experimental system. It will be used by both the Experimental Combat Operations Centre and the Experiment Control Centre.

Urban Warrior will apply the modular concept. Tactical systems will gather data and be augmented by additional, instrumentation-only components when the necessary data cannot be gathered any other way. This will allow a proof-of-concept system to be developed to work towards:

- Defining the degree of precision needed in three-dimensions to support urban area instrumentation;
- Developing a system (eg. differential GPS adapted to urban terrain) that provides such accuracy within the urban environment;
- Taking maximum advantage of 'plug and play' components;
- Defining the level of instrumentation needed inside buildings to support urban operations.

Current inside-building instrumentation requires each room to be instrumented, and is extremely expensive. The instrumentation level required for MOUT training, would need to be determined. For example, is it good enough to simply know which building an entity is in rather than pinpointing the exact room? The IMMACCS technology used in Urban Warrior will stimulate development in a variety of areas of future C2 systems, eg:

1. *Information Understanding*

Whereas current systems process data, future systems (eg., IMMACCS) will need to process information. The key to the assistance capabilities of IMMACCS is that the system has some 'understanding' of the information that it is processing. The commander interacts with a computer display that consists of hundreds of real world entities that all have some 'understanding' of each other's nature, interests and objectives.

2. ***Collaborative Tools***

Hopefully future systems will be a collection of powerful collaborative tools, not a library of canned solutions. This approach is intended to overcome the deficiencies of legacy systems in which built-in solutions to predetermined problems often differ significantly from the complex operational and tactical situations encountered by Marine forces.

IMMACCS is a collaborative decision-support system in which the operators interact with computer-based agents (i.e. decision-making tools) to solve problems that cannot be precisely nor easily predetermined.

3. System Reasoning:
C2 Systems will need to incorporate agents that are able to reason about the characteristics and the relationships of the many real world entities (objects), all of which have meaning.

For example, during Urban Warrior IMMACCS will include agents that apply their knowledge to:

- weapon selection and deconfliction,
- monitor nuclear, chemical and biological hazards,
- filter and report intelligence,
- monitor enemy engagements,
- warn friendly units of previous incidences of sniper fire before they enter another region in the battlefield;
- advise on Rules of Engagement; and,
- anticipate logistical resupply requirements.

IMMACCS will also use mentor agents that may be created to represent the interests of warfighters and warfighting machines. Mentor agents extend the capabilities of Marines at all levels by:

- warning friendly units of enemy intrusions into their territory,
- looking out for the occurrence of events specified by the operator (such as satisfaction of critical information requirements), and
- providing safeguards against fratricide.

4. Continuous Integration
There is a need to integrate planning, execution and training within one common C2 user environment. During Urban Warrior, IMMACCS will see the computer-based agents and the Marine hosts continuously collaborate as they interact with each other in changing battlefield situations.

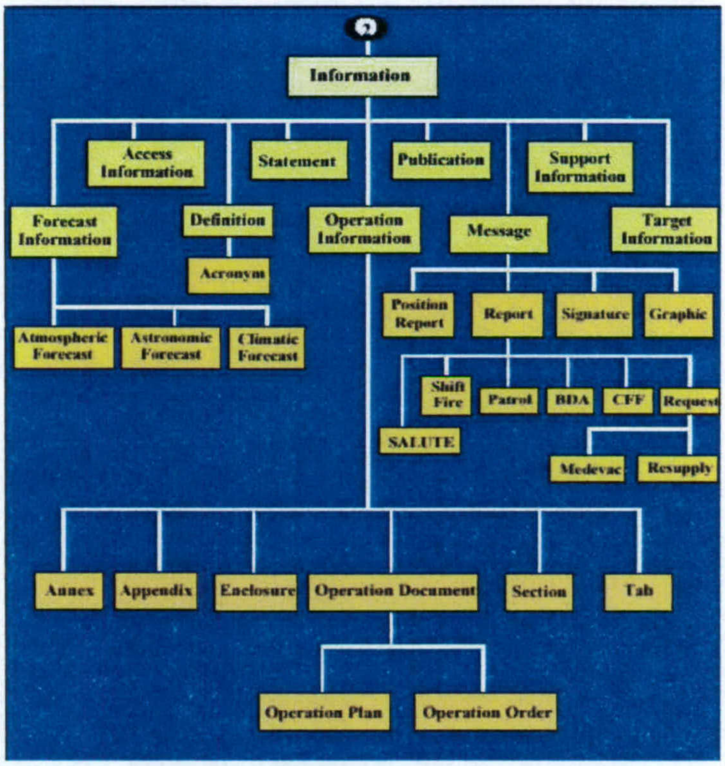
In this respect IMMACCS reflects the complexity of the real world where problem solutions need to be continuously reviewed as conditions change, and it becomes increasingly difficult and inconvenient to separate planning, execution, re-planning, and training functions into artificially discrete activities.

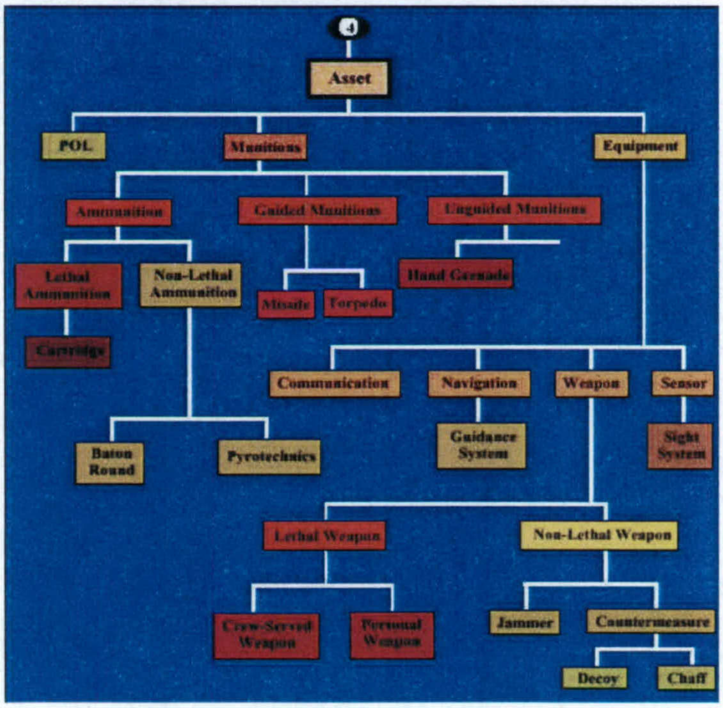
Urban Warrior will:

- Experiment with means to allow communications inside buildings;
- Identify appropriate AAR analysis tools for urban instrumentation;
- Apply lessons about analysis tool requirements that were learned during earlier MCWL experiments.

These will be applied to tool development and modification for Urban Warfare analysis, synthesis and learning.

Appendix E: IMMACCS Object Model representation for Information and for Assets





DISTRIBUTION LIST

A review of US Army and Marine Command and Control Systems

Brendan J Kirby and Paul S Gaertner

AUSTRALIA

DEFENCE ORGANISATION

	No. of copies
Task Sponsors	
DGPP-A	1
DG3ID	1
DIM-A	1
DOISD	1
S&T Program	
Chief Defence Scientist	shared copy
FAS Science Policy	shared copy
AS Science Corporate Management	shared copy
Director General Science Policy Development	shared copy
Counsellor Defence Science, London	Doc Data Sheet
Counsellor Defence Science, Washington	Doc Data Sheet
Scientific Adviser to MRDC, Thailand	Doc Data Sheet
Scientific Adviser Joint	1
Navy Scientific Adviser	Doc Data Sht & Dist List
Scientific Adviser - Army	1
Air Force Scientific Adviser	Doc Data Sht & Dist List
Scientific Adviser to the DMO M&A	Doc Data Sht & Dist List
Scientific Adviser to the DMO ELL	Doc Data Sht & Dist List
Systems Sciences Laboratory	
Chief of Land Operations Division	Doc Data Sht & Dist List
Research Leader Land Systems	Doc Data Sht & Dist List
Task Manager (Wayne Johnson)	1
Authors:	
Brendan Kirby	1
Paul Gaertner	1
DSTO Library and Archives	
Library Edinburgh	1 + Doc Data Sheet
Defence Archives	1
Capability Systems Division	
Director General Maritime Development	Doc Data Sheet

Director General Land Development	1
Director General Capability and Plans	Doc Data Sheet
Assistant Secretary Investment Analysis	Doc Data Sheet
Director Capability Plans and Programming	Doc Data Sheet
Director Trials	Doc Data Sheet

Office of the Chief Information Officer

Deputy CIO	Doc Data Sheet
Director General Information Policy and Plans	Doc Data Sheet
AS Information Strategies and Futures	Doc Data Sheet
AS Information Architecture and Management	Doc Data Sheet
Director General Australian Defence Simulation Office	Doc Data Sheet
Director General Information Services	Doc Data Sheet

Strategy Group

Director General Military Strategy	Doc Data Sheet
Director General Preparedness	Doc Data Sheet
Assistant Secretary Strategic Policy	Doc Data Sheet
Assistant Secretary Governance and Counter-Proliferation	Doc Data Sheet

Navy

Director General Navy Capability, Performance and Plans, Navy Headquarters	Doc Data Sheet
Director General Navy Strategic Policy and Futures, Navy Headquarters	Doc Data Sheet
Commander Maritime Operational Analysis Centre, Building 89/90 Garden Island Sydney NSW	Doc Data Sht & Dist List

Army

DNCW-A	1
LHQ (Attn: COL DEV)	1
WOCOMD (Attn: DCSOCAUST DEV	1
ABCA National Standardisation Officer, Land Warfare Development Sector, Puckapunyal	e-mailed Doc Data Sheet
SO (Science), LHQ, Victoria Barracks, Paddington NSW 2021	1
SO (Science), Deployable Joint Force Headquarters (DJFHQ) (L), MILPO Gallipoli Barracks, Enoggera QLD 4052	1
SO (Science), 3 Bde, Lavarack Barracks, MILPO Townsville QLD 4813	1
SO (Science), 1 Bde, Robertson Barracks, Palmerston NT 0830	1
SO (Science), Training Command – Army, HQ TC-A, Suakin Drive, Georges Heights NSW 2088	1
SO (Science), Special Forces, Maritime Headquarters, Garden Island, NSW	1

Intelligence Program

DGSTA Defence Intelligence Organisation	1
Manager, Information Centre, Defence Intelligence Organisation	email pdf

Assistant Secretary Corporate, Defence Imagery and Geospatial Organisation	Doc Data Sheet

Defence Materiel Organisation

Deputy CEO	Doc Data Sheet
Head Aerospace Systems Division	Doc Data Sheet
Head Maritime Systems Division	Doc Data Sheet
Chief Joint Logistics Command	Doc Data Sheet
Head Materiel Finance	Doc Data Sheet

Defence Libraries

Library Manager, DLS-Canberra	Doc Data Sheet
Library Manager, DLS - Sydney West	Doc Data Sheet

OTHER ORGANISATIONS

National Library of Australia	1
NASA (Canberra)	1

UNIVERSITIES AND COLLEGES

Australian Defence Force Academy	
Library	1
Head of Aerospace and Mechanical Engineering	1
Hargrave Library, Monash University	Doc Data Sheet
Librarian, Flinders University	1

OUTSIDE AUSTRALIA

INTERNATIONAL DEFENCE INFORMATION CENTRES

US Defense Technical Information Center	2
United Kingdom - Dstl Knowledge Services	2
Canada - Defence Research Directorate R&D Knowledge & Information Management (DRDKIM)	1
NZ Defence Information Centre	1

ABSTRACTING AND INFORMATION ORGANISATIONS

Library, Chemical Abstracts Reference Service	1
Engineering Societies Library, US	1
Materials Information, Cambridge Scientific Abstracts, US	1
Documents Librarian, The Center for Research Libraries, US	1

SPARES		5
Total number of copies:	**Printed**	**45**
	PDF	**1**

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
DOCUMENT CONTROL DATA

1. PRIVACY MARKING/CAVEAT (OF DOCUMENT)

2. TITLE A Review of US Army and Marine Command and Control Systems	3. SECURITY CLASSIFICATION (FOR UNCLASSIFIED REPORTS THAT ARE LIMITED RELEASE USE (L) NEXT TO DOCUMENT CLASSIFICATION) Document (U) Title (U) Abstract (U)
4. AUTHOR(S) Brendan J Kirby and Paul S Gaertner	5. CORPORATE AUTHOR Systems Sciences Laboratory PO Box 1500 Edinburgh South Australia 5111 Australia

6a. DSTO NUMBER	6b. AR NUMBER	6c. TYPE OF REPORT	7. DOCUMENT DATE
DSTO-TN-0596	AR 013-260	Technical Note	November 2004

8. FILE NUMBER	9. TASK NUMBER	10. TASK SPONSOR	11. NO. OF PAGES	12. NO. OF REFERENCES
E9505-23-124	ARM 98/271	DGPP-A	40	20

13. URL on the World Wide	14. RELEASE AUTHORITY
http://www.dsto.defence.gov.au/corporate/reports/DSTO-TN-0596.pdf	Chief, Land Operations Division

15. SECONDARY RELEASE STATEMENT OF THIS DOCUMENT

Approved for public release

OVERSEAS ENQUIRIES OUTSIDE STATED LIMITATIONS SHOULD BE REFERRED THROUGH DOCUMENT EXCHANGE, PO BOX 1500, EDINBURGH, SA 5111

16. DELIBERATE ANNOUNCEMENT

No Limitations

17. CITATION IN OTHER DOCUMENTS Yes

18. DEFTEST DESCRIPTORS

Situation awareness
Battlefield information systems
Digital battlefield
Command and control systems
Systems analysis
Interoperability

19. ABSTRACT
The US Army Battle Command System (ABCS) is an integrated system of command and control software, computers, communications and networking devices. A summary of the ABCS is provided, giving an overview of how the Force XXI Battle Command Brigade and Below (FBCB2) system fits into the overarching scheme of providing battlefield awareness to the Army. FBCB2 aims to provide digital battle command and situational awareness to mounted and dismounted tactical combat, combat support, and combat service support commanders, leaders and soldiers. The US Marine's Integrated Marine Multi-Agent Command and Control System is also discussed in the light of the development of an Australian Battlefield Command Support System.